

Measurements of CO During SEAC⁴RS Using the New DACOM Instrument



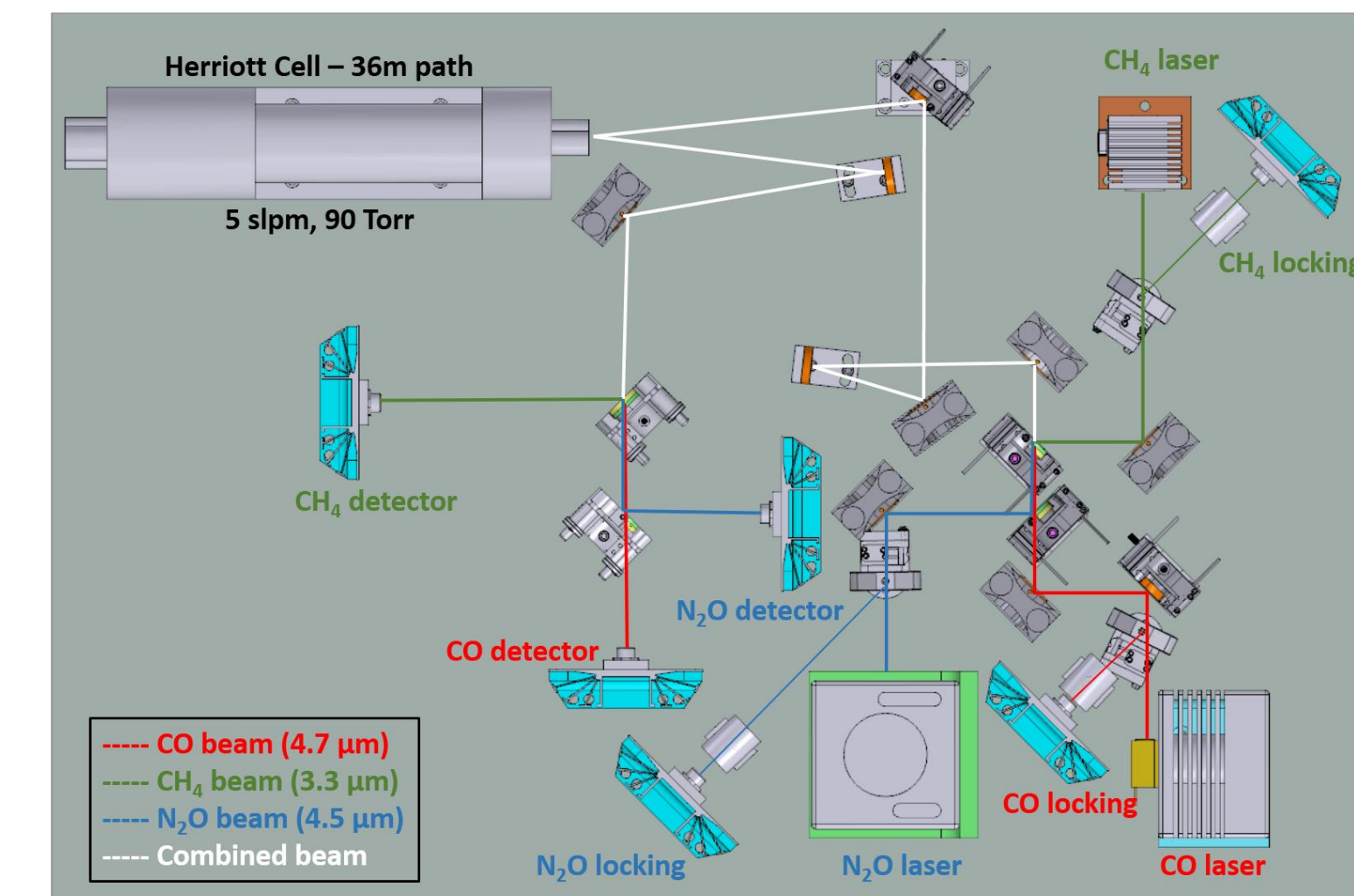
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ABSTRACT

A new mid-infrared diode laser absorption instrument was built for SEAC⁴RS to provide in situ measurements of carbon monoxide (CO) from the DC-8 platform. This instrument replaced the older DACOM (Differential Absorption Carbon monOxide Measurements) instrument (DACOM "Classic") due to a logistical conflict with the ongoing DISCOVER-AQ measurement campaign. The new DACOM used a room-temperature quantum cascade laser (QCL) in place of the older cryogenically-cooled lead-salt laser, and used a National Instruments compact real-time computer with a field-programmable gate array (FPGA) to control the entire instrument and collect and analyze data. Despite early difficulties exacerbated by scheduling and procurement challenges, the instrument was able to provide quality CO concentration data for nearly the entire campaign. We present relevant aspects of the new instrument design and operation as well as selected data from the SEAC⁴RS campaign illustrating instrument performance. Data quality is examined and comparisons are shown with data gathered from a COTS instrument and from the Whole Air Sampler (WAS), which both also flew on the DC-8.



DACOM History / Heritage

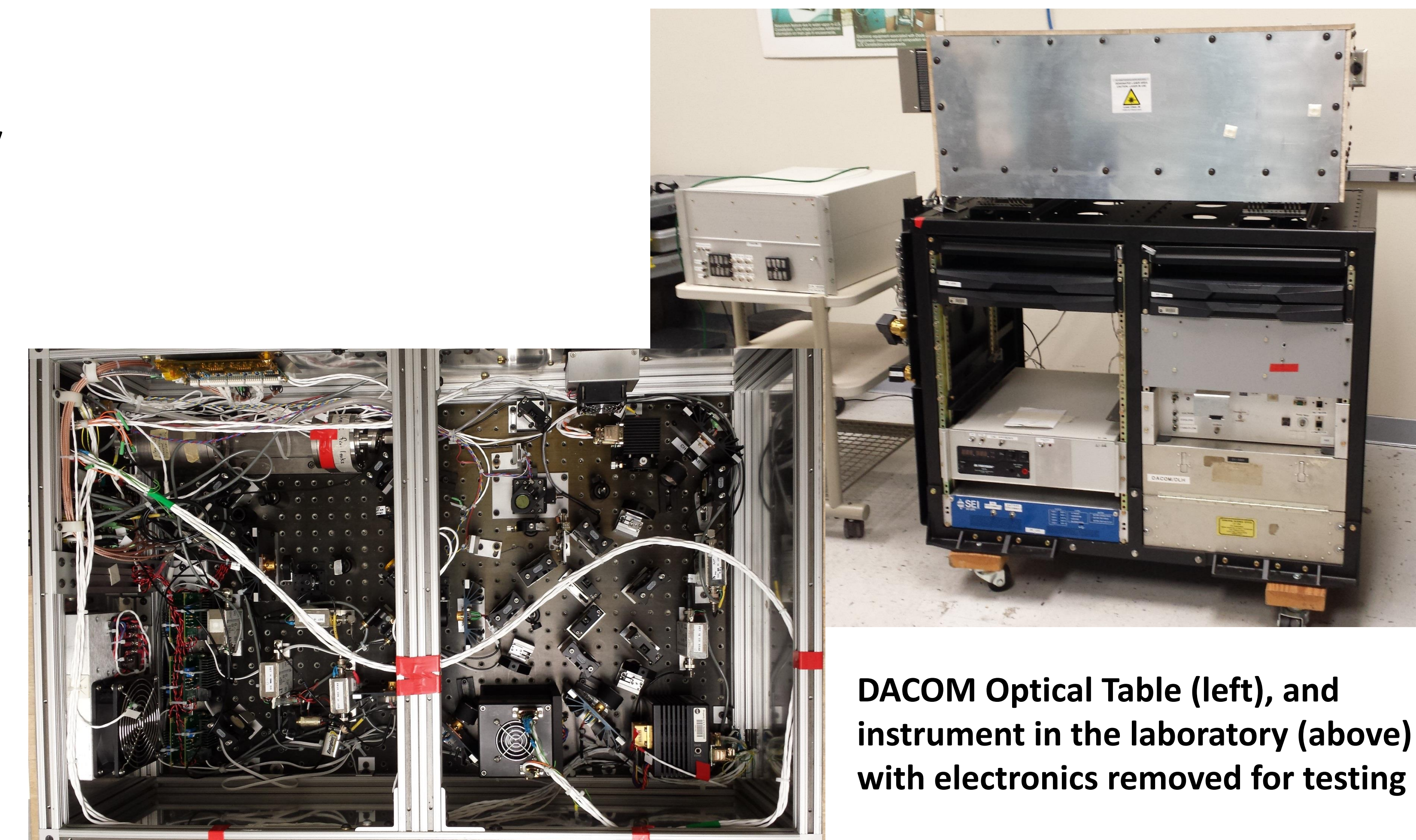
- Airborne measurements of CO date to mid-1970s
- Later added CH₄, N₂O channels
- Data rate nominally 1 Hz, but capable of higher rates for measurements of flux using eddy correlation technique
- Mid-IR lasers and detectors cryogenically cooled
 - Low power, poor spatial and spectral mode quality

Need for Additional DACOM Instrument

- SEAC⁴RS delayed from 2012 to 2013, overlapped with DISCOVER-AQ/TX
 - DACOM committed to support both campaigns
- Opportunity to design and build a new DACOM, with:
 - Equivalent or better performance
 - Room temperature lasers and detectors
 - All-Digital Control, Laser Stabilization, Modulation/Demodulation
 - National Instruments cRIO / FPGA
 - Reduced level of hands-on operator interaction
- CO-only version flew on DC-8 during SEAC⁴RS (2013)
- Full 3-channel version flew on P-3B during DISCOVER-AQ/CO (2014)

New DACOM – Design Features

- Common with DACOM Classic**
 - 3-wavelength mid-IR diode laser absorption
 - Line-locked multi-harmonic wavelength modulation spectroscopy
 - 36 m Herriott cell, 5 slpm dried sampling, ~90 Torr
 - Periodic calibration using NOAA-assayed standards
 - Thermally stabilized enclosure
- New Features**
 - Room-temperature lasers
 - High-power, single mode QCLs (CO, N₂O), ICL (CH₄)
 - HgCdTe detectors with 3-stage TEC
 - Real-Time Operating System allows all-digital stabilization and control
 - Better temperature control of optical enclosure
 - Instrument much more amenable to autonomous operation
 - Better beam quality and laser stability results in fewer required adjustments in-flight

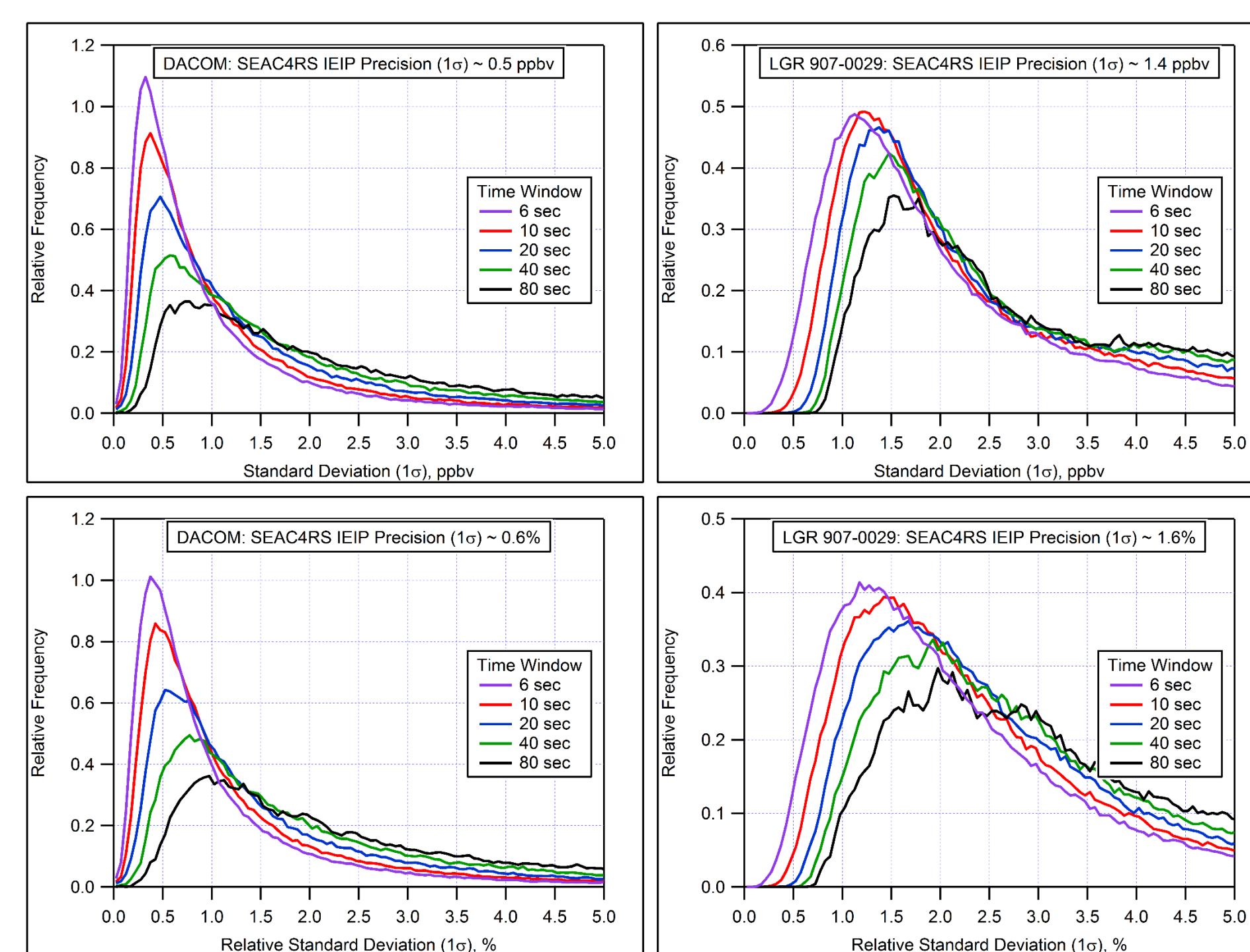
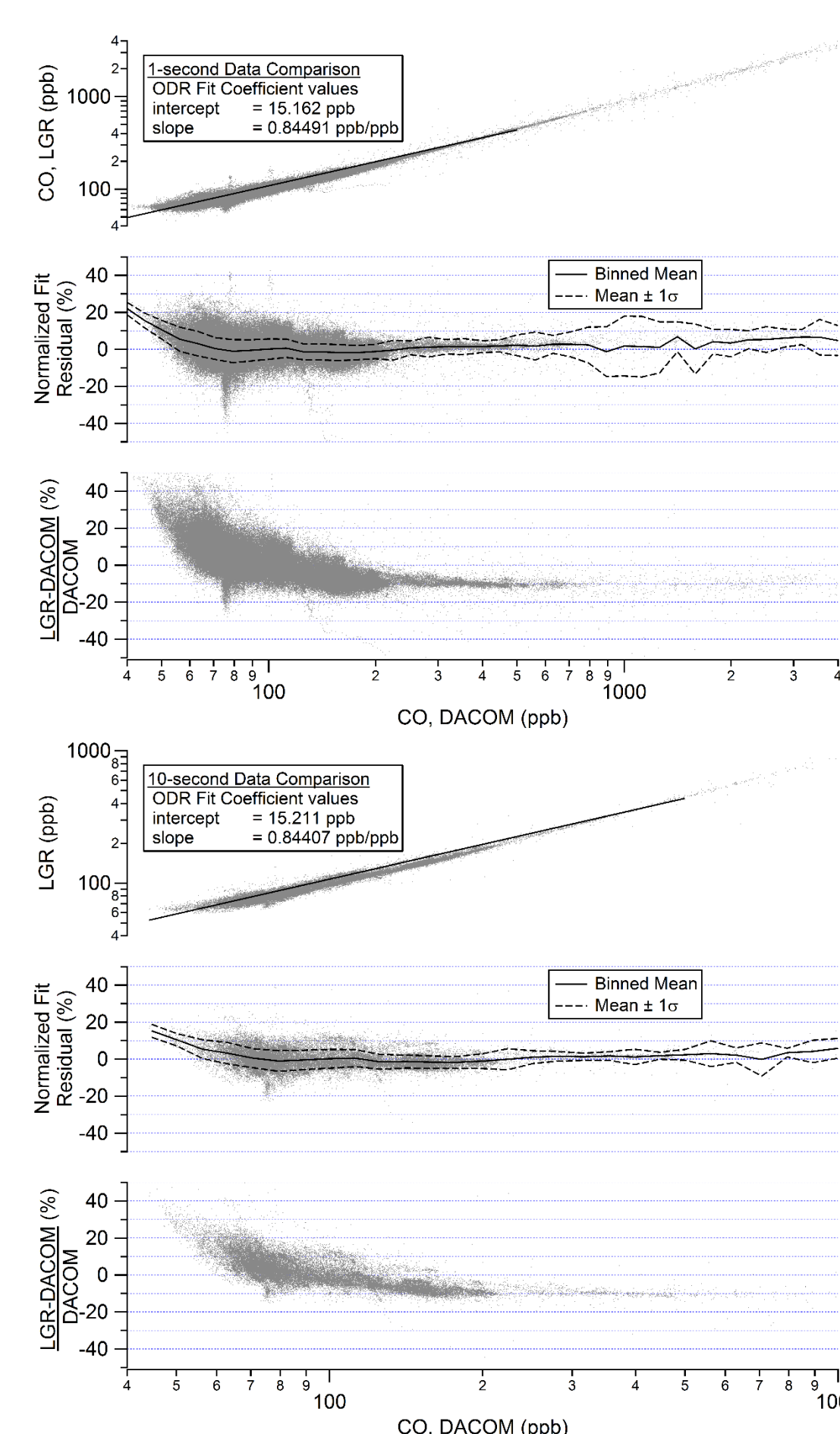


DACOM Optical Table (left), and instrument in the laboratory (above) with electronics removed for testing



DACOM Data from SEAC⁴RS

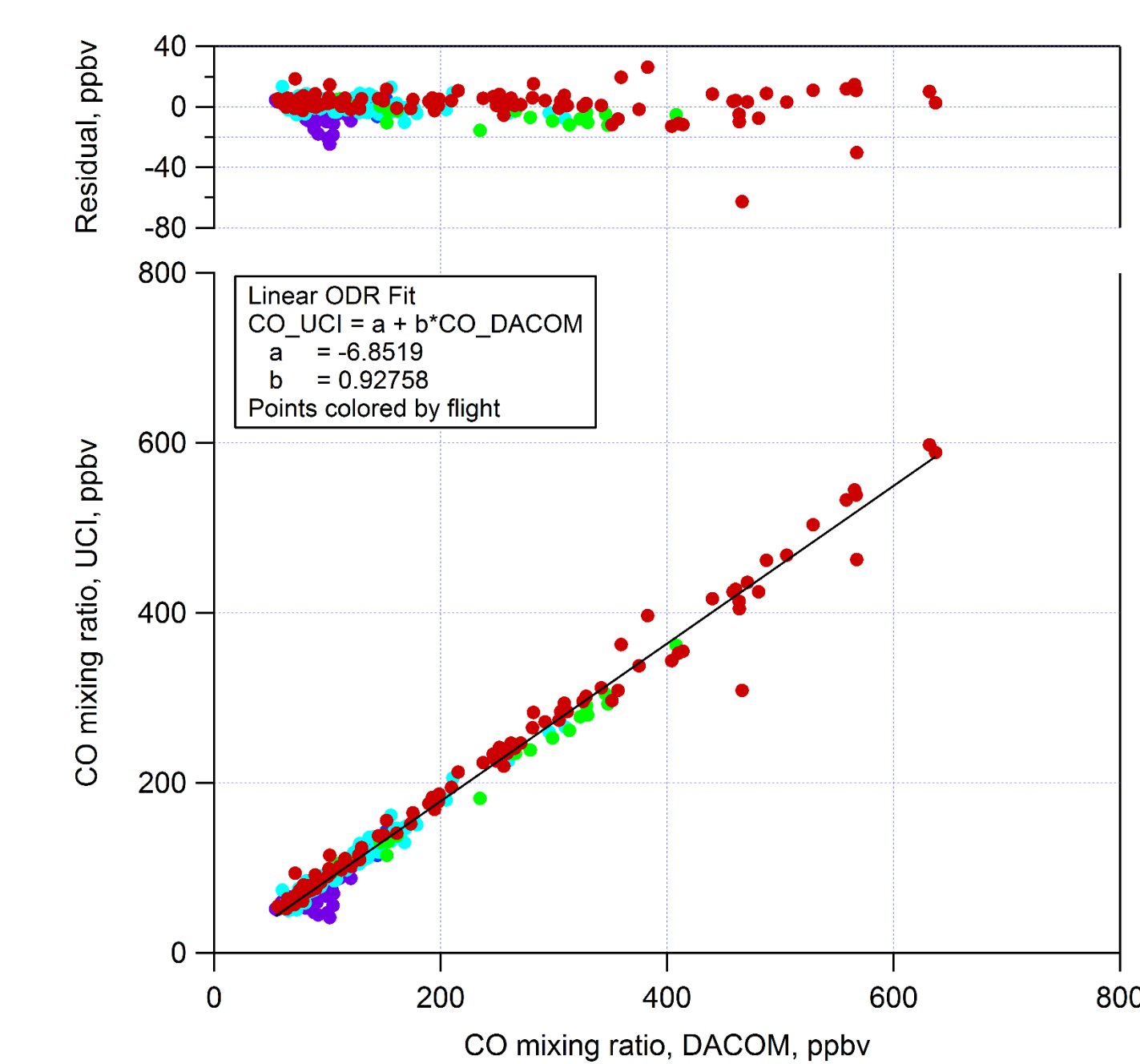
Data from a LGR 907-0029 were available for most flights during SEAC⁴RS, and provide a means for assessing DACOM data quality



- DACOM data, calibrated in-flight using NOAA/ESRL-assayed cylinders, were used to correct LGR data; corrected LGR data used during two flights when DACOM data were unavailable
- IEIP method, developed to analyze ICARTT data, show DACOM precision is close to that obtained by "Classic" instrument in prior campaigns

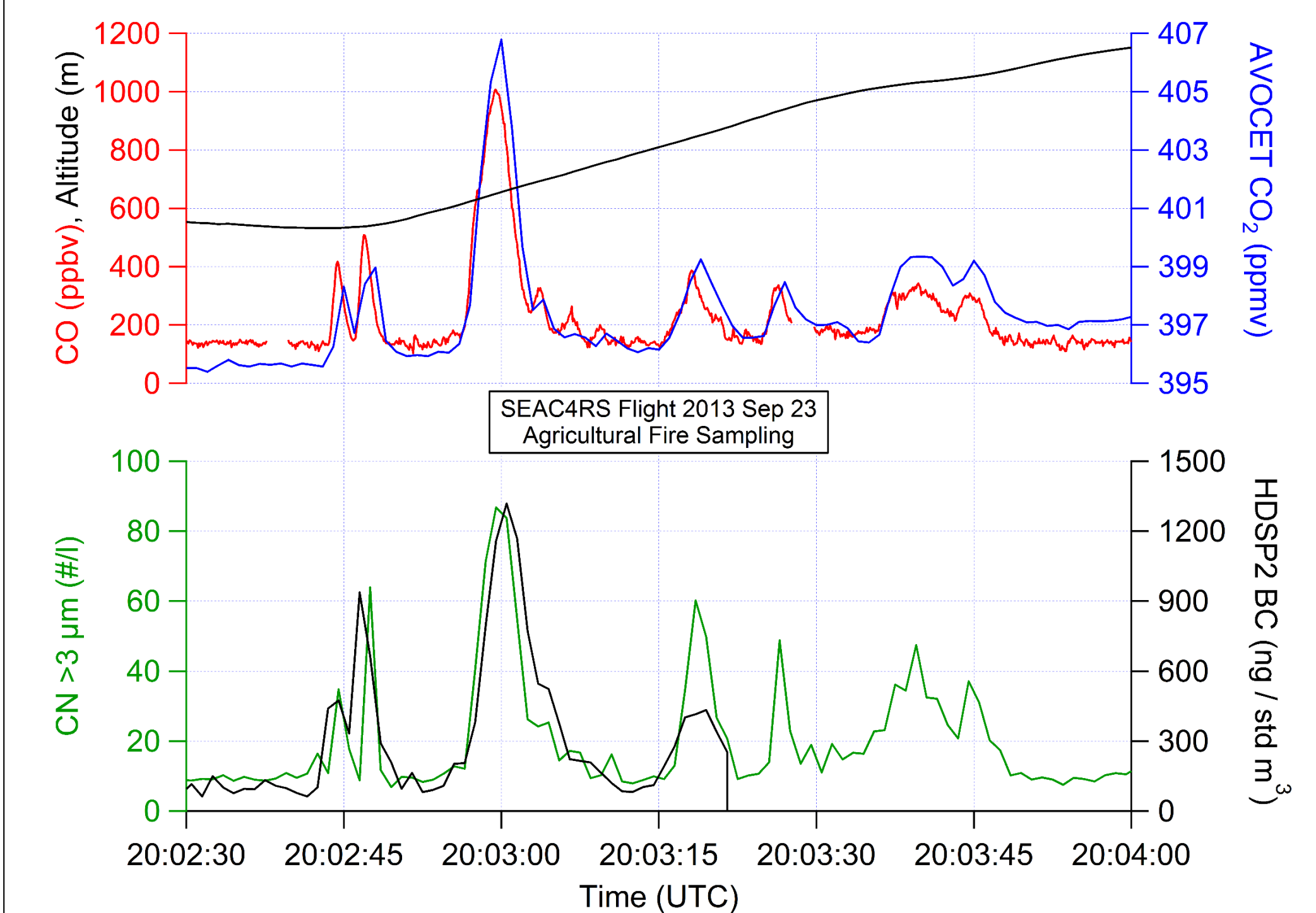
IEIP analysis of DC3 data, using DACOM "Classic," shows somewhat higher precision than achieved during SEAC⁴RS

CO data from the UCI Whole Air Sampler were available for 5 common flights during SEAC⁴RS



- DACOM data averaged over WAS integration times
- Agreement between DACOM and WAS CO measurements during SEAC⁴RS is typically within 10% or 10 ppbv

10 Hz DACOM CO data, in context of other *in situ* measurement, showing time response and precision in a time series showing sampling of agricultural fires



- DACOM data shown at 10 Hz rate indicate better than 1-sec resolution
- Small, short-lived features, shown in other measurements, are clearly well-described by the new DACOM instrument

Thanks to the UCI group for the WAS CO data, the LARGE and AVOCET groups for the LGR CO data, the LARGE group for the CN data, and the NOAA group for the BC data.